Interannual atmospheric variability forced by the deep equatorial Atlantic Ocean

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Summary

Vertically alternating deep zonal jets of short vertical wavelength with a period of about 4.5 yr and amplitudes of more than 10 cm/s are observed, in the deep Atlantic, to propagate their energy upwards, towards the surface. They are linked, at the sea surface, to equatorial zonal current anomalies and eastern Atlantic temperature anomalies that have amplitudes of about 6 cm/s and 0.4°C, respectively, and are associated with distinct wind and rainfall patterns. Although deep jets are also observed in the Pacific and Indian oceans, only the Atlantic deep jets seem to oscillate on interannual timescales. The oscillatory behaviour can be used to improve predictions of sea surface temperature (SST) in the tropical Atlantic.

Introduction

Climate variability in the tropical Atlantic Ocean is sensitive to changes in SST particularly affecting deep atmospheric convection over the ocean and surrounding continents. During boreal summer the seasonal strengthening of easterlies along the equator leads to the development of the eastern Atlantic SST cold tongue centered slightly south of the equator at about 10°W. The interannual variability of the onset of the cold tongue is found to be strongly linked to the onset of the West African Monsoon. Traditionally, climate variability in the tropical Atlantic has focused on the zonal and meridional modes. Here, new observations acquired during the Tropical Atlantic Climate Experiment (TACE, 2006-2011) are analyzed to identify a previously overlooked mode of tropical Atlantic climate variability that originates in the deep equatorial Atlantic Ocean.

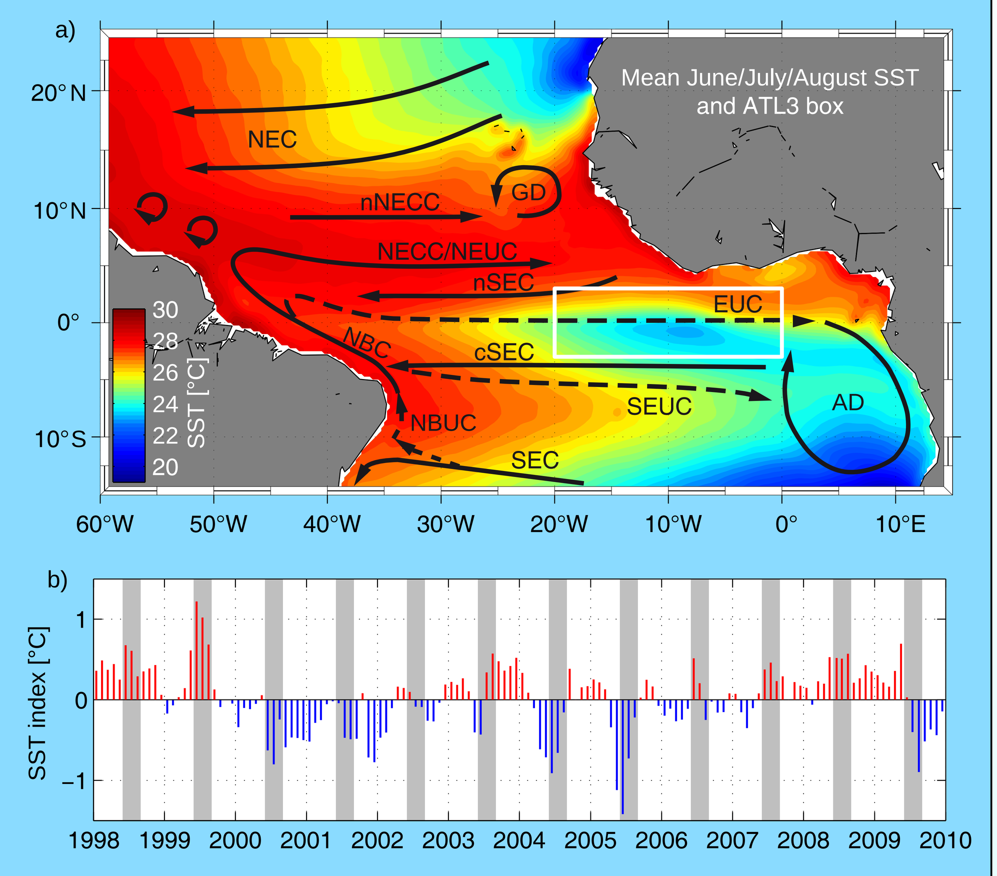


Fig.1: Mean June/July/August SSTs in the tropical Atlantic (a). Also included are the main surface (solid) and thermocline (dashed lines) current bands. The white box in (a) defines the region for the ATL3 SST index shown in (b).

4.5-yr climate cycle

Anomalous westerlies along the Equator, convergent meridional wind anomalies particularly in the western tropical Atlantic, and positive rainfall anomalies in a wide belt around the Equator are associated with positive SST anomalies. A 4.5-yr cycle is also found in the surface geostrophic zonal velocity anomaly at the Equator as well as in the 1,000-m zonal velocity from Argo floats. Phases of eastward surface flow coincide with SST warm phases in the eastern equatorial Atlantic.

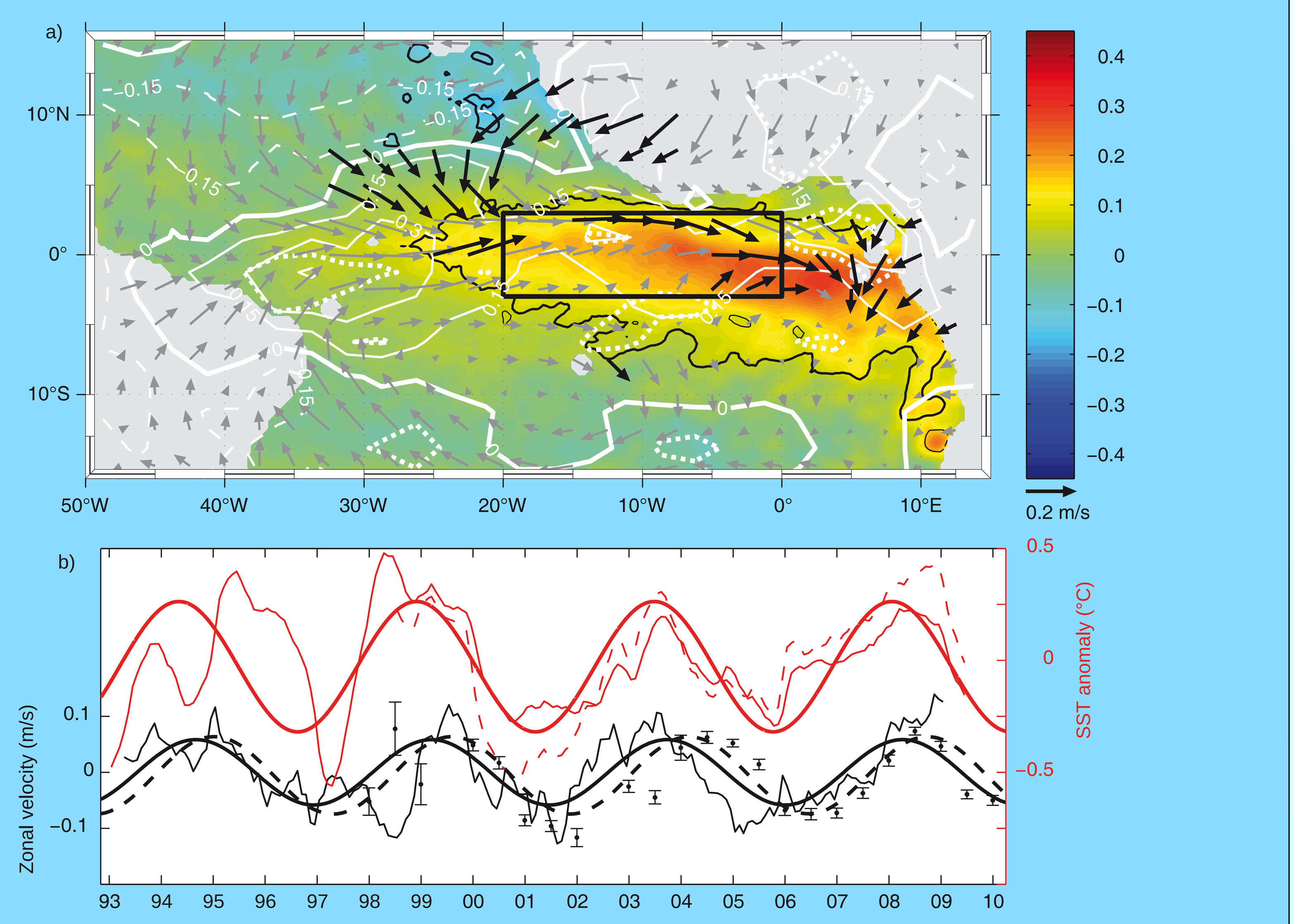


Fig.2: (a) Regression of SST, surface wind and rainfall (white contours, mm/d) on the harmonic fit of the ATL3 SST anomalies. (b) ATL3 SST anomaly (microwave optimally interpolated SST, red dashed; HadISST, red thin solid) with 1,670-d harmonic fit (red thick solid), surface geostrophic zonal velocity anomaly (Equator, 35°W–15°W; black thin solid) with 1,670-d harmonic fit (black thick solid), and 1,000-m zonal velocity (1°S–1°N, 35°W-15°W; black dots with standard errors) with 1,670-d harmonic fit (black thick dashed).

Atlantic equatorial deep jets (EDJs)

Moored observations reveal the existence of EDJs oscillating at a period of about 4.5 yr. EDJs are associated with downward phase propagation from below the Equatorial Undercurrent (EUC) at about 200-m depth to about 2,000-m depth that corresponds, according to linear internal wave theory, to upward energy propagation.

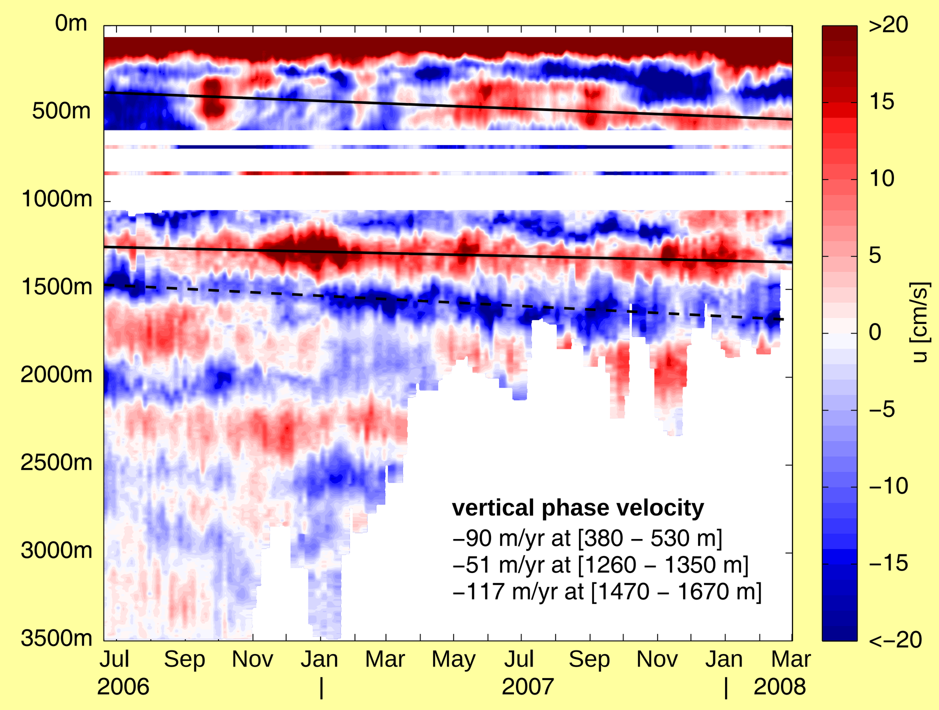


Fig.3: Zonal velocity at the Equator, 23°W, acquired by a mooring equipped with an ADCP, single-point current meters and a moored profiler. Linearized phase lines with vertical phase velocities of EDJs are given in the figure.

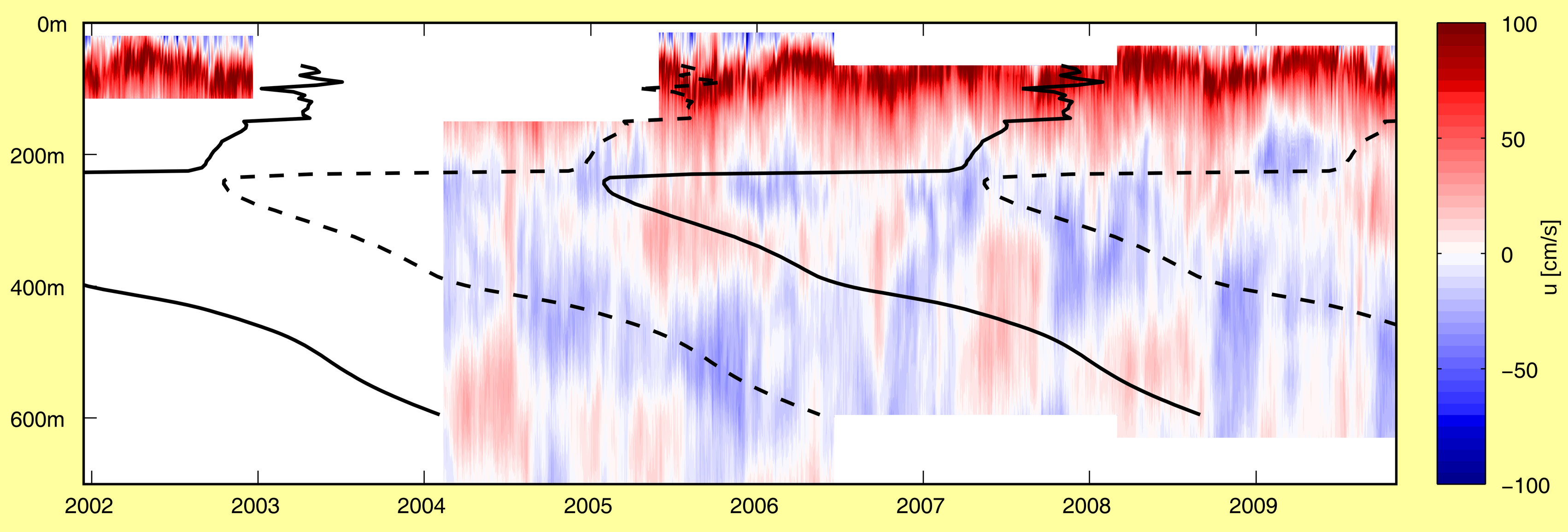
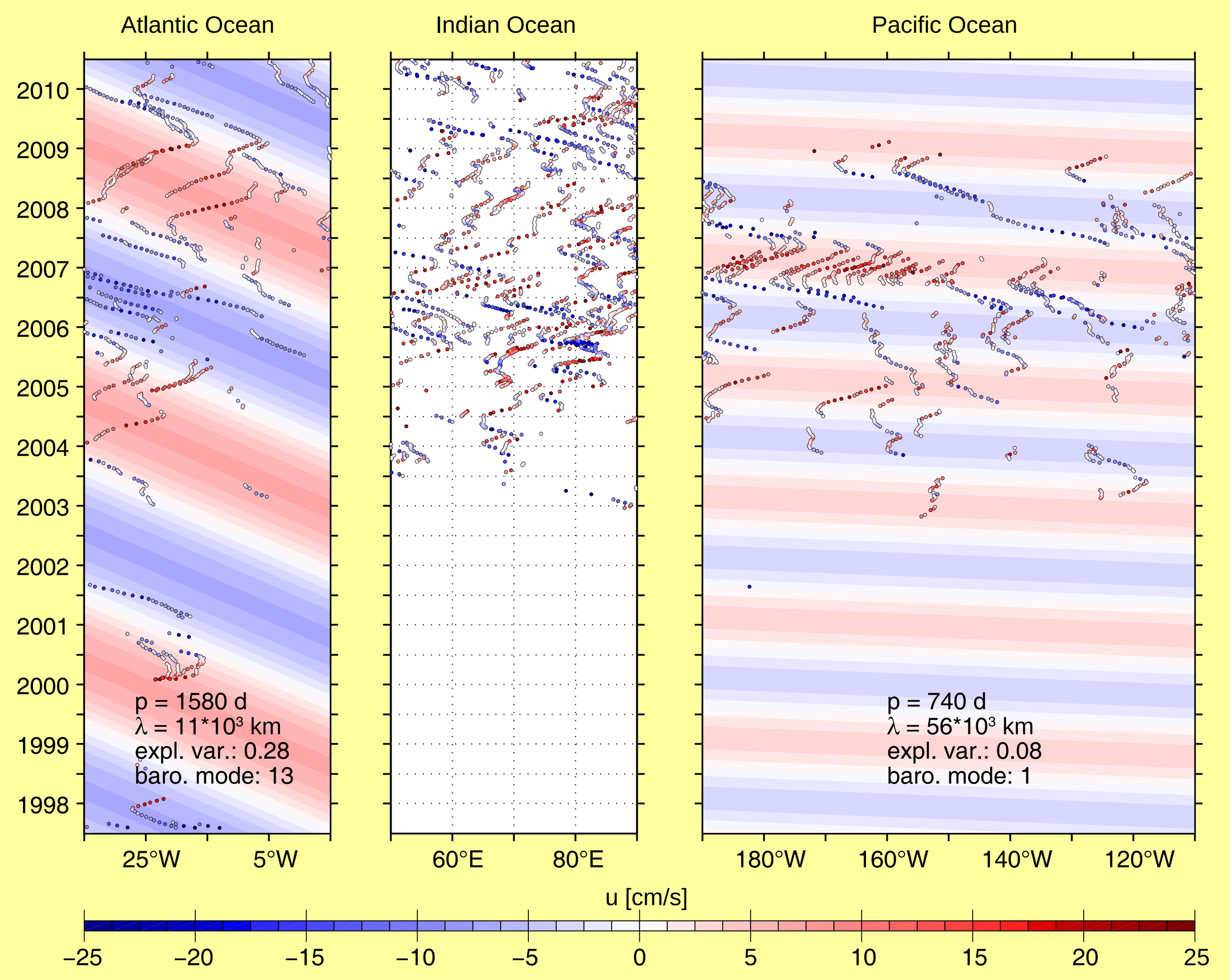


Fig.4: Zonal velocity at the Equator, 23°W, acquired by different moored ADCPs. Phase lines are obtained from harmonic analysis using a period of 1,670 d.

Global deep equatorial flow

On interannual timescales, high-baroclinic mode waves, i.e. the EDJs, dominate in the Atlantic while in the Pacific the dominant signal is associated with low-baroclinic-mode variability likely wind-generated. The Indian Ocean Argo float velocities are characterized by merely incoherent signals.

Fig.5: Equatorial zonal velocities from 1,000-m Argo float drift data (1°S-1°N). The dominant interannual variability in the Atlantic and Pacific oceans obtained by maximizing explained variance using a plane wave fit is visualized by colour shadings.



Seasonality of climate cycle

The amplitude of the 1,670-d cycle of zonal velocity is seasonally independent whereas the corresponding amplitudes of the ATL3 SST anomalies at this period are instead strongest during boreal summer and November/December. Such behaviour is consistent with the equatorial zonal surface flow forced by interior ocean dynamics, whereas associated SST variations are seasonally modulated.

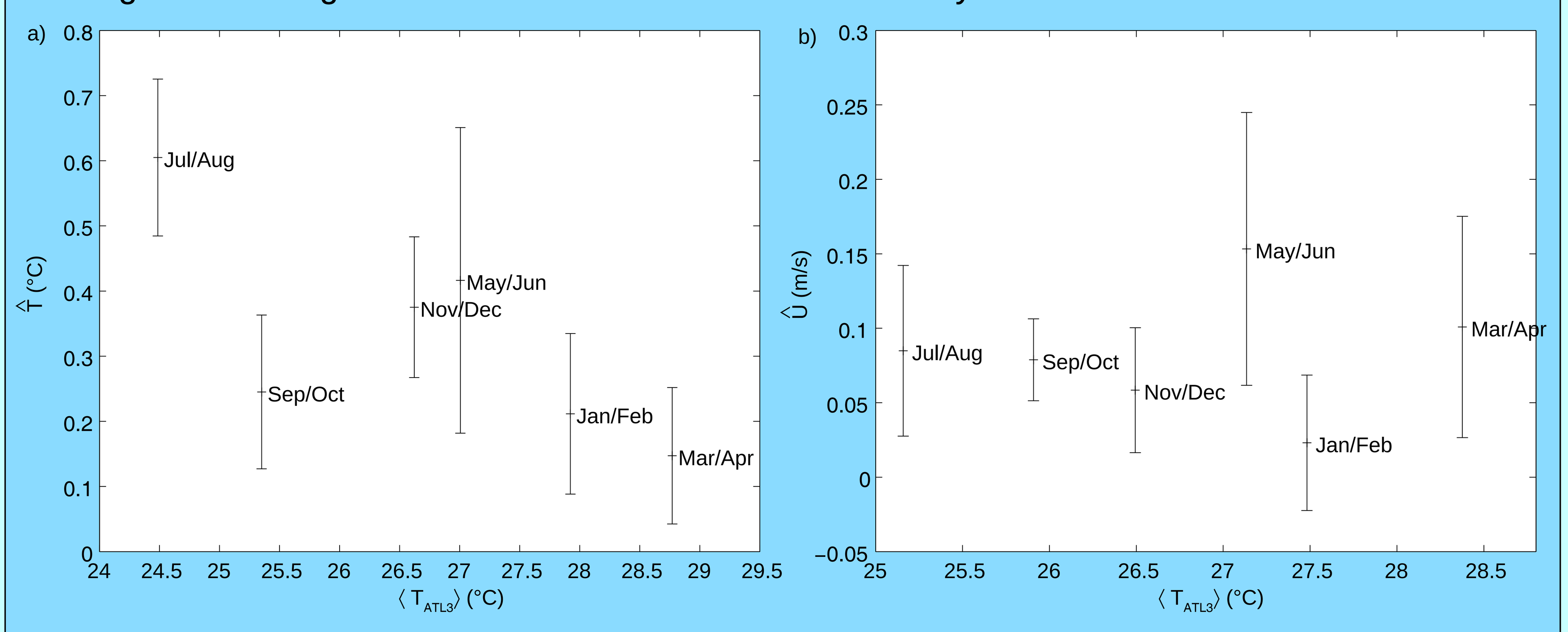


Fig.6: 1,670-d harmonic amplitude of bimonthly averaged (a) ATL3 SST indices and (b) geostrophic zonal velocity (Equator, 35°W-15°W) indices (b).

Acknowledgement

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Reference

Brandt, P., A. Funk, V. Hormann, M. Dengler, R. J. Greatbatch, J. M. Toole, Interannual atmospheric variability forced by the deep equatorial Atlantic Ocean, Nature, 473, 497-500, doi: 10.1038/nature10013, 2011.